



Experimental Investigations From the Operation of a 2 kW Brayton Power Conversion Unit and a Xenon Ion Thruster

David Hervol
Analex Corporation, Brook Park, Ohio

Lee Mason, Arthur Birchenough, and Luis Pinero
Glenn Research Center, Cleveland, Ohio

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at <http://www.sti.nasa.gov>
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at 301-621-0134
- Telephone the NASA Access Help Desk at 301-621-0390
- Write to:
NASA Access Help Desk
NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076



Experimental Investigations From the Operation of a 2 kW Brayton Power Conversion Unit and a Xenon Ion Thruster

David Hervol
Analex Corporation, Brook Park, Ohio

Lee Mason, Arthur Birchenough, and Luis Pinero
Glenn Research Center, Cleveland, Ohio

Prepared for the
Space Technology and Applications International Forum (STAIF-2004)
sponsored by the American Institute of Physics
Albuquerque, New Mexico, February 8–12, 2004

National Aeronautics and
Space Administration

Glenn Research Center

Acknowledgments

The work described in this paper was performed by the staff of Glenn Research Center at Lewis Field for Project Prometheus, the Nuclear Systems Program under the Office of Space Science (Code S) at NASA Headquarters. The authors also wish to acknowledge the technical support provided by Glenn personnel: George Soulas, John Miller, Jack Schuerger, and Don Fong. The opinions expressed in this paper do not necessarily reflect the views of the JIMO project.

This report contains preliminary findings, subject to revision as analysis proceeds.

Available from

NASA Center for Aerospace Information
7121 Standard Drive
Hanover, MD 21076

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22100

Available electronically at <http://gltrs.grc.nasa.gov>

Experimental Investigations From the Operation of a 2 kW Brayton Power Conversion Unit and a Xenon Ion Thruster

David Hervol¹
Analex Corporation
Brook Park, Ohio 44142

Lee Mason,² Art Birchenough,³ and Luis Pinero⁴
National Aeronautics and Space Administration
Glenn Research Center
Cleveland, Ohio 44135

ABSTRACT

A 2 kW Brayton Power Conversion Unit (PCU) and a xenon ion thruster were integrated with a Power Management and Distribution (PMAD) system as part of a Nuclear Electric Propulsion (NEP) Testbed at NASA's Glenn Research Center. Brayton converters and ion thrusters are potential candidates for use on future high power NEP missions such as the proposed Jupiter Icy Moons Orbiter (JIMO). The use of existing lower power test hardware provided a cost-effective means to investigate the critical electrical interface between the power conversion system and ion propulsion system. The testing successfully demonstrated compatible electrical operations between the converter and the thruster, including end-to-end electric power throughput, high efficiency AC to DC conversion, and thruster recycle fault protection. The details of this demonstration are reported herein.

INTRODUCTION

Nuclear Electric Propulsion (NEP) has been identified as an enabling technology for future NASA space science missions, such as the Jupiter Icy Moons Orbiter (JIMO) now under study. NEP provides various potential mission benefits including large payload mass fractions, the ability to visit multiple mission targets with a single spacecraft, high power and long duration in-situ science investigations, and high data-rate communications. An important element of the NEP spacecraft is the power conversion system, which converts the reactor heat to electrical power for use by the ion propulsion system and other spacecraft loads. The electrical integration of the power converter and ion thruster represents a key technical challenge in establishing NEP technology feasibility.

This technical hurdle was extensively addressed on December 1, 2003 when a closed Brayton cycle Power Conversion Unit (PCU) was tested with a gridded ion thruster at NASA's Glenn Research Center (GRC). The test demonstrated end-to-end power throughput, and marked the first-ever coupling of a Brayton turbo-alternator and a gridded ion thruster, both of which are candidates for use on JIMO-type missions (Mason, 2003). The testing was conducted at Glenn's Vacuum Facility #6 (VF6) where the Brayton unit was installed in the 3-meter diameter vacuum test port and the ion thruster was installed in the 7.6 m diameter main chamber as shown in Figure 1.

The Brayton test unit was a fully integrated power conversion system including turbo-alternator, recuperator, and gas cooler with Helium-Xenon (HeXe) working fluid designed for operation up to 2 kW (Hervol, 2003). The heat source used in the test was a series of silicon-carbide electrical resistance heaters contained in a shell and tube heat exchanger that heated the HeXe gas to over 1000 K, simulating a fission reactor source. A commercial chiller with a pumped ethylene glycol cooling loop provided waste heat rejection, simulating a space radiator system. The Brayton PCU is shown in Figure 2.

¹Mechanical Systems Branch, Glenn Engineering and Scientific Support Organization, 21000 Brookpark Road, Cleveland, Ohio 44135; Ph.: 216-433-9624, Fax: 216-433-8311, E-mail: david.hervol@grc.nasa.gov

²Thermo-Mechanical Systems Branch, Power and On-Board Propulsion Technology Division

³Electrical Systems Development Branch, Power and On-Board Propulsion Technology Division

⁴Onboard Propulsion Branch, Power and On-Board Propulsion Technology Division

The ion thruster used in the test was an Engineering Model (EM) of the NASA Solar Electric Propulsion Technology Application Readiness (NSTAR) gridded ion thruster used successfully as the main propulsion system on the NASA Deep Space 1 Mission in 1998 (Brophy, 2002). The NSTAR thruster is rated for operation up to 2.3 kW, providing 92 milli-newtons thrust and 3100 seconds specific impulse using xenon propellant. The EM NSTAR thruster, installed in VF6's main chamber, is shown in Figure 3.

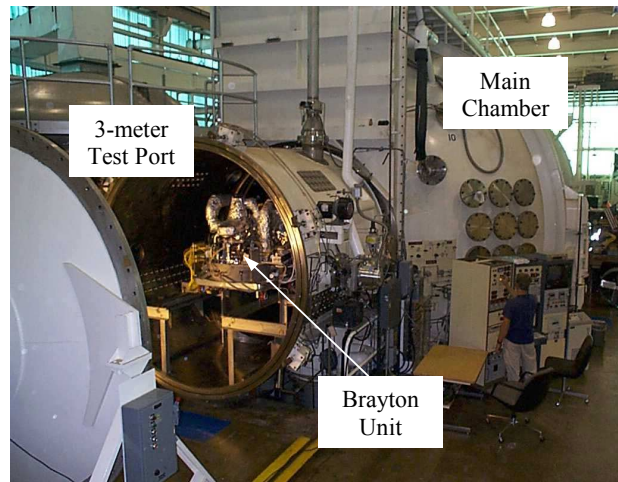


FIGURE 1. GRC Vacuum Facility #6

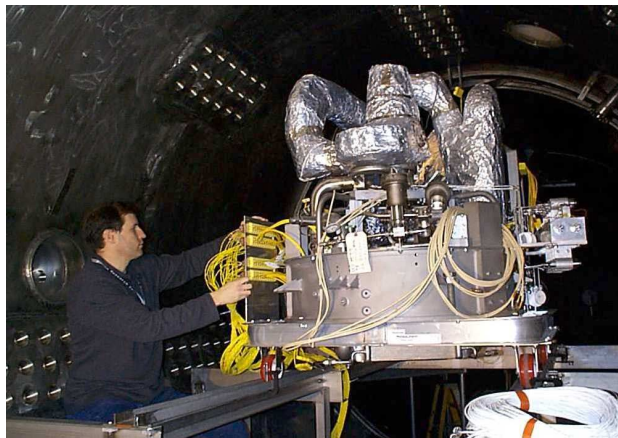


FIGURE 2. Brayton Power Conversion Unit



FIGURE 3. NSTAR Engineering Model Thruster

The use of existing low-power test hardware provided a cost-effective and expeditious means to examine the critical electrical interface between the converter and thruster. The similarity in power rating between the Brayton and the NSTAR made for a natural pairing. While this test was limited in power to the 2 kW-class, the power management techniques are applicable to the higher power levels projected for NEP. For the test, the Brayton PCU was operated at 1.6 kW AC electrical output and 53000 rpm. The NSTAR thruster was operated at various power levels between 0.7 and 1.7 kW. The Brayton system provided power directly to the thruster beam supply, up to 1.4 kW, while the remainder of the thruster loads were satisfied by laboratory power supplies.

The Brayton alternator power was routed through a fully representative Power Management & Distribution (PMAD) system, designed and built in-house at GRC. The PMAD converted the 55 volt (RMS, line-to-neutral), 3-Phase AC alternator output to 1100 volts-DC for use by the thruster beam supply. The AC to DC conversion was accomplished using a transformer-rectifier-filter approach. This same approach is being studied for possible implementation in the ion thruster Power Processing Units under study within the JIMO project. The PMAD system also provided Brayton speed and voltage control via a Parasitic Load Radiator (PLR), designed to maintain a constant load on the alternator regardless of thruster demand. High speed load transfer between the PLR and the thruster beam supply provided fault protection during thruster recycles. Recycles are intermittent and unpredictable electrical transients that occur with ion thrusters resulting in a momentary short circuit condition. If not properly managed, thruster recycles could cause harmful effects to the thruster grids, PMAD, and/or the Brayton rotating equipment. The testing verified that a recycle could be detected, power switched from the beam supply within several milli-seconds (msec), and power switched back to the beam supply in less than a second, all while maintaining the thruster in operating mode.

The successful completion of this test provides the following important advances in NEP technology development:

- Demonstrated end-to-end electric power throughput from a Brayton power conversion unit to an ion thruster in a representative vacuum environment.
- Demonstrated high efficiency, AC to DC conversion using a radiation tolerant transformer/rectifier/filter design approach that is applicable to JIMO-class Power Processing Units.
- Demonstrated thruster recycle fault protection using high speed load transfer from the beam supply to a parasitic load radiator without adverse energy deposition on the thruster grids or harmful transients on the Brayton rotor.

TEST CONFIGURATION

The overall test schematic is shown in Figure 4. The Brayton PCU is installed in the 3-meter test port and the NSTAR thruster is installed in the main chamber at VF6. During the test, the test port was operated at rough vacuum ($\sim 1 \times 10^{-3}$ torr) and was isolated from the main chamber by a 3-meter gate valve. The rough vacuum provides a suitable environment for the multi-foil insulation (MFI) used on the hot-surfaces of the Brayton unit to minimize heat leakage. The main chamber was operated at hard vacuum ($\sim 1 \times 10^{-6}$ torr) as required for operation of the thruster.

Both the Brayton and NSTAR thruster utilize external electronic racks for power, control, and data acquisition. The three Brayton electronic racks are pictured in Figure 5. The PMAD console (left-most rack in Figure 5) includes a startup power supply for the Brayton alternator, speed and voltage control electronics, high voltage converter stage, and an air-cooled PLR. The PMAD console also supplies the high voltage power feed to the NSTAR power supply rack, which distributes the power to the thruster. A logic control circuit between the Brayton PMAD and NSTAR power console provides a high voltage safety disconnect. The electrical design is discussed in further detail in a the POWER MANAGEMENT AND DISTRIBUTION section.

The Brayton power supply console (right-most rack in Figure 5) includes the operator controls for the gas heater and commercial chiller. The Brayton working fluid is heated by three silicon-carbide resistive elements in series that are inserted into a shell and tube heat exchanger. The heating elements do not come into contact with the working fluid and heat the inner surface of the gas heater exclusively by radiation. The heater has a dedicated 480 volt power supply that utilizes an industrial style Proportional-Integral-Derivative controller providing constant power to the resistive elements as specified by the test operator. The chiller, located in the test facility basement, uses a 50 percent ethylene glycol 50 percent water mixture. The chiller provides coolant flow rates of approximately 3 gallons per minute at a controlled supply temperature of 273 K for heat loads up to 4.5 kWt.

Test data is acquired using a commercial data logger connected to a desktop computer contained in the data acquisition rack (center rack in Figure 5). The data acquisition software performs real time calculations of PCU heat input and heat rejection, cycle efficiency, compressor and turbine efficiencies, recuperator effectiveness and mass

flow rate. A representative data screen print showing all pressures, temperatures, power levels, voltages, currents, flow rates, and calculated values, is shown in Figure 6. Test data was concurrently saved to data files for post processing.

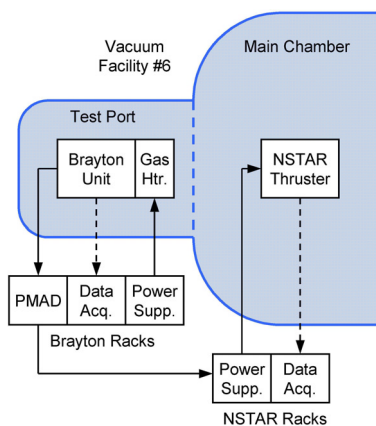


FIGURE 4. Brayton/NSTAR Test Schematic

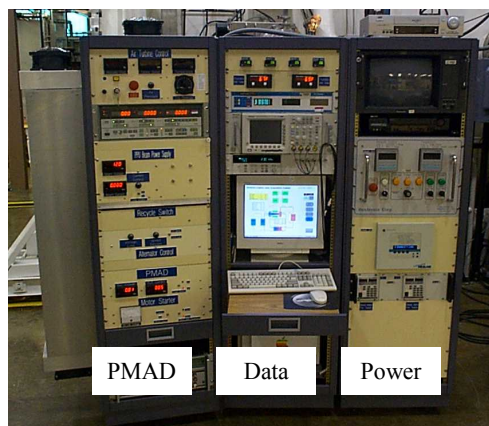


FIGURE 5. Brayton Electronic Racks

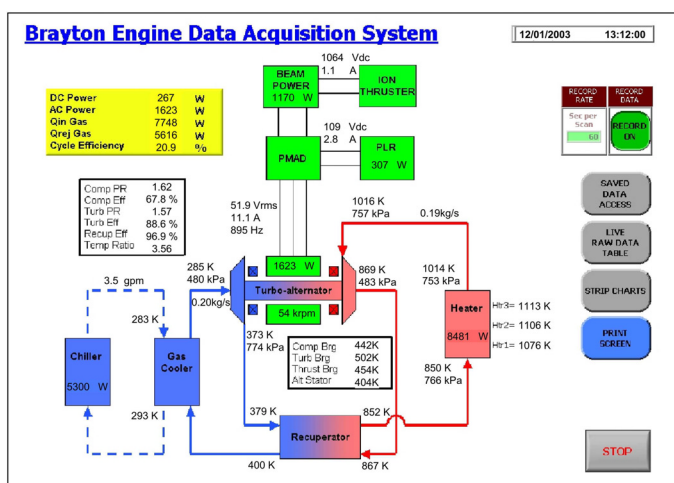


FIGURE 6. Brayton Data Acquisition Screen

The NSTAR power console provides power for the various thruster loads. In addition to the beam supply load which is satisfied via the Brayton PMAD, the NSTAR thruster requires power for the accelerator grid, discharge cathode, and neutralizer cathode during steady-state operation and for the neutralizer heater during startup. NSTAR data acquisition is accomplished with digital multi-meters for steady-state voltages and currents, and a digital oscilloscope to capture high speed electrical transients.

POWER MANAGEMENT AND DISTRIBUTION (PMAD)

The PMAD electrical control system performs the functions of PCU startup, alternator output voltage and rotor speed control, and converts the low voltage AC output of the alternator to 1100 volts-DC as required for the NSTAR beam supply. The control system operates autonomously except for operator commands to begin motor starting and enable the high voltage output. A DC power supply simulating a battery provides electrical input to the motor start inverter for startup motoring. The PMAD control system also provides redundant over-speed shutdown protection for the turboalternator.

The Brayton PCU includes a 3-phase permanent magnet alternator that produces an output voltage proportional to the alternator speed, and inversely proportional to the applied load (Mason, 1997). The output voltage is approximately 55 volts-AC (RMS, line-to-neutral), which can be rectified with a 3-phase full wave bridge to provide 120 volts-DC. The electrical load on the alternator is controlled to regulate the rotational speed. If the load torque is equal to the torque supplied by the rotor, the speed will be constant. Increasing the alternator loading decreases the speed, and decreasing the alternator loading increases the speed. This technique is called parasitic load speed control. The amount of parasitic load applied to the machine is controlled, based on the speed and voltage set points specified by the test operator. The power in the parasitic load is then dissipated as waste heat using an air cooling system. The PMAD overall block diagram is shown in Figure 7.

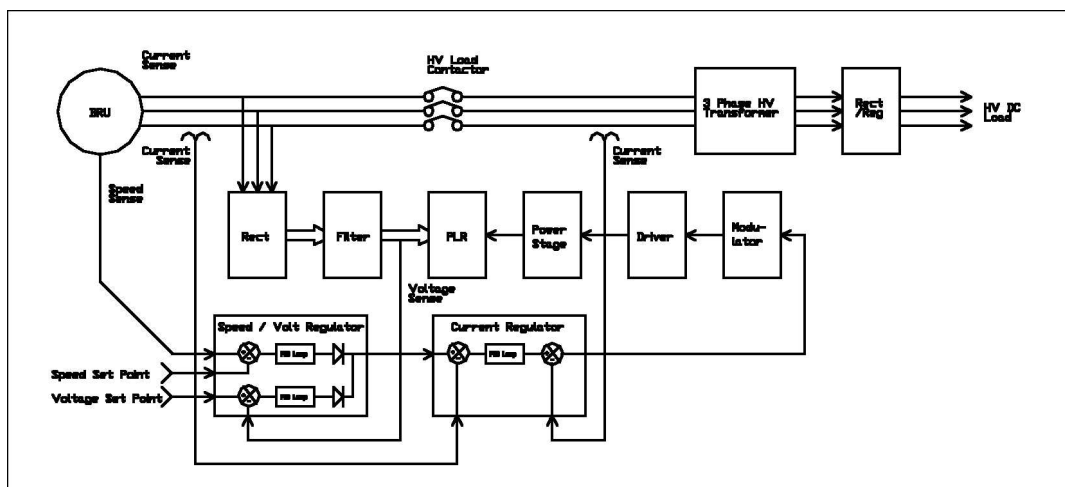


FIGURE 7. Overall PMAD Block Diagram

The conversion to high voltage DC for the ion thruster beam power supply is accomplished with a transformer – rectifier – filter (TRF) set as shown in Figure 8, followed by a voltage regulation stage. The TRF approach provides a high efficiency, radiation tolerant solution to the high voltage DC converter requirement. The use of the transformer greatly reduces the number of radiation sensitive semi-conductor devices typically associated with DC-DC converters, while providing higher efficiency. The Brayton PMAD system is designed for autonomous load sharing between the PLR and the thruster load. If the thruster load is turned-off or experiences a momentary electrical transient, the PLR automatically compensates by adding resistive load to maintain a constant overall load on the alternator. A Remote Power Controller (RPC) at the TRF provides a shutoff relay on the high voltage DC thruster load to accommodate on/off cycles. The TRF assembly in the PMAD rack is shown in Figure 9.

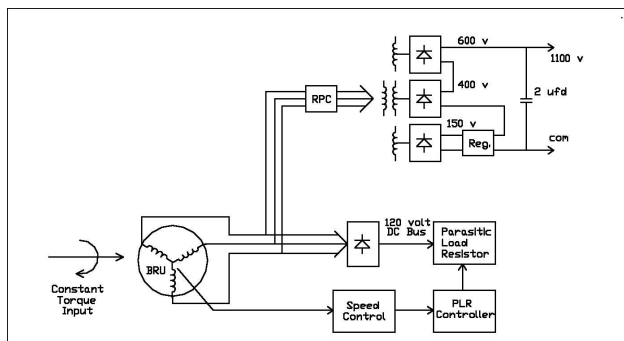


FIGURE 8. Transformer Rectifier Filter (TRF) Schematic



FIGURE 9. TRF Board in PMAD Rack

TEST APPROACH

The integrated test of the Brayton PCU and NSTAR thruster was preceded by several functional checkout tests to assure electrical compatibility and verify stable operation. The checkout testing was performed in a progressive manner with each test providing a higher fidelity simulation of the actual hardware. First, the Brayton PMAD system was thoroughly exercised with an Alternator Test Rig (ATR), which simulated the Brayton alternator using an air turbine drive source. The ATR and PMAD were then tested with an ion thruster resistive load bank, during which power variations and thruster recycles were evaluated.

This phase of testing revealed that the switching between the Brayton PMAD and the thruster power controller was causing unacceptable charge transfer to the thruster load bank, during simulated thruster recycles. High speed data traces indicated that the Brayton PMAD was transferring an average of 6 amps over about 12 msec or about 72 milli-coulombs (mC). Recent findings indicate that excessive charge transfer during a thruster recycle could potentially cause electrode grid damage and degrade thruster performance and life. The present charge transfer limit for the molybdenum grids used on the EM NSTAR thruster is estimated at 9 mC. As a solution, a high speed Field Effect Transistor (FET) switch was placed in series with the shutoff relay in the Brayton PMAD system. This reduced the large shutdown transient time to less than 250 micro-seconds and the charge transfer to about 4 mC. The thruster recycle transient and Brayton system response is described in more detail in the TEST RESULTS section.

After the performance of the new switch was verified, the PMAD rack was successfully operated with the Brayton PCU at the design conditions planned for the NSTAR test. The Brayton PCU was disconnected, replaced by the ATR, and the PMAD output was connected to the thruster via the NSTAR power rack. Testing was performed at thruster power levels identical to those used previously with the load bank simulator and the testing indicated that the new FET switch was sufficient to limit the charge transfer to an acceptable level during thruster recycles.

Finally, the Brayton PCU was connected to the PMAD system and NSTAR thruster for the actual integrated system test. The test plan called for NSTAR thruster operation at three initial power settings (test points 1, 2, 3) and three optional power settings (test points 4, 5, 6) as outlined in Table 1. The optional test points were to be acquired only if the first three points were achieved without difficulty. These test point settings were obtained from the NSTAR Flight Throttling Table and correspond to pre-determined propellant flow, beam current, and beam voltage settings. In Table 1, thruster power represents the total electrical power required by the thruster including beam supply and auxiliary thruster loads. Beam power is the product of beam voltage and beam current, and accounts for about 80 percent of the total thruster power.

TABLE 1. Brayton/NSTAR Test Power Levels

Test Point	NSTAR Throttle Level	Thruster Power (kW)	Beam Voltage (VDC)	Beam Current (amps)	Beam Power (kW)
1	TH2	0.74	1100	0.52	0.57
2	TH6	1.22	1100	0.91	1.00
3	TH10	1.70	1100	1.30	1.43
4	TH8	1.46	1100	1.10	1.21
5	TH7	1.34	1100	1.00	1.10
6	TH3	0.86	1100	0.61	0.67

TEST RESULTS

The integrated system test was conducted on December 1, 2003 during which the NSTAR thruster was successfully operated at all six test points from Table 1. The majority of the testing was performed with the Brayton PCU at a power level of 1.6 kW and rotor speed of 53000 rpm (883 Hz). The corresponding turbine inlet and compressor inlet temperatures were 1020 and 290 K, respectively. Thermal-to-electric efficiency was approximately 22 percent.

Previous testing of this unit, in its current heat source and chiller configuration, has resulted in 1.8 kW power output and 24 percent thermal-to-electric efficiency at a turbine inlet temperature of 1070 K and a compressor inlet temperature of 280 K (Hervol, 2003).

The maximum NSTAR operating power was 1.7 kW (TH10), with approximately 1.4 kW supplied by the Brayton system to the beam supply. At this operating point, the PMAD efficiency was about 91 percent based on total losses associated with the high voltage TRF stage and the PLR stage. The majority of the power loss (~6 percent) was due to core loss in the high voltage transformer. The excessive core loss fraction was a consequence of using a readily available commercial transformer that was not optimized for this application. Efficiency improvements in the TRF stage are anticipated at JIMO-class power levels using optimized components.

Stable thruster operation at all six power levels was demonstrated. Steady-state operation was maintained for a minimum of 30 minutes at each test point. While in steady-state operating mode, the thruster was subjected to a number of operator induced recycles by placing a metallic rod with an insulated grip between the beam and accelerator circuits, thereby creating a momentary short-circuit condition. This procedure simulates a “natural” recycle that occurs intermittently and unpredictably with ion thrusters. The recycle transient was considered the greatest challenge in achieving a successful system demonstration. The recycle simulation produced no adverse effects on either the NSTAR thruster or the Brayton unit. Several “natural” recycles also occurred during the test period without incident.

Figure 10 shows the beam voltage and current during an induced NSTAR recycle at the TH10 operating point. The voltage drops off in microseconds while the current drops off in about 0.06 seconds. The initial current spike at the moment of the voltage drop-off is the primary concern for causing thruster grid damage. The beam current that follows the initial spike is the result of residual current transfer from the accelerator circuit, and not attributed to the Brayton PMAD performance. Beam voltage is restored in about 0.8 seconds and the thruster is returned to pre-recycle operation in less than 1.3 seconds.

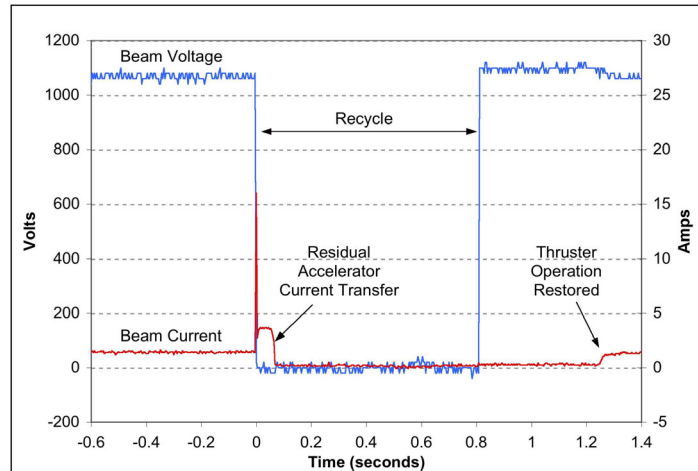


FIGURE 10. Beam Voltage and Current During Simulated Thruster Recycle at TH10 Operating Point

Figure 11 shows the beam voltage and current for the first 100 msec after the induced recycle on TH10. The current spikes to 16 amps over 250 micro-seconds then drops to 5 amps for 4 msec before the NSTAR recycle logic circuit commands the beam current off. The charge transfer directly attributed to the high voltage Brayton PMAD is 4 mC. The total charge transfer with the additional 4 msec NSTAR command logic delay is about 24 mC. The 4 msec delay could be reduced with faster control commands from the NSTAR power console. The residual accelerator current remains on the beam circuit for 60 msec. This accelerator current transfer is the result of a combination of factors including the NSTAR recycle control circuit, the accelerator power supply characteristics, and the use of the

shorting-rod between the beam and accelerator circuits as required to initiate the recycle. This phenomenon would not occur during a “natural” recycle.

Figure 12 shows the Brayton alternator response to the same recycle. During the recycle, the alternator experiences 4 cycles at a high current, low voltage condition before the charge transfer transient is complete and nominal operation is restored with the PLR absorbing the full alternator load. The 4 msec alternator transient directly corresponds to the NSTAR logic command delay. Following the recycle, the alternator and Brayton converter exhibited no adverse effects or performance degradation.

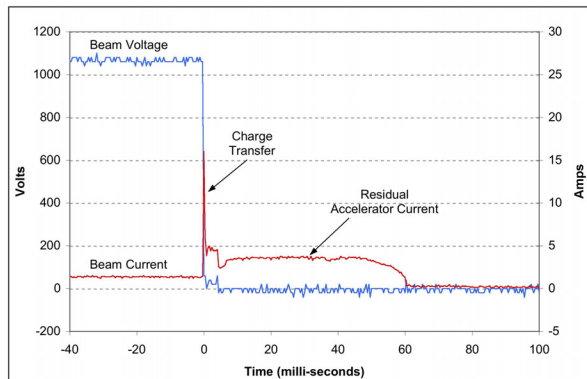


FIGURE 11. Beam Voltage and Current for First 100 msec Following Recycle

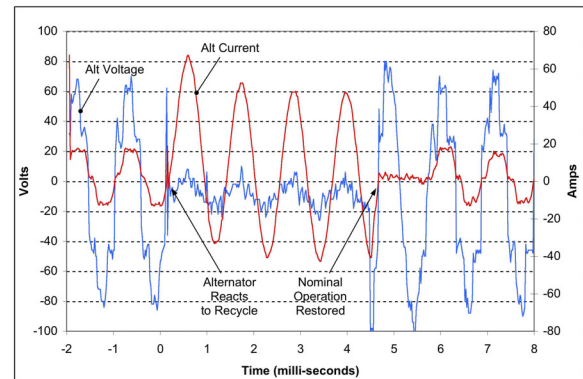


FIGURE 12. Alternator Output During Induced Thruster Recycle

The Brayton PMAD system provided steady-state power with voltage ripple of less than 1 percent peak-to-peak and negligible current ripple as shown in Figure 13. The voltage ripple indicates a characteristic frequency of 5 kHz as a result of the 3-phase full wave rectification of the 883 Hz alternator output. For comparison, Figure 14 shows the ripple trace for the laboratory DC beam power supply in the NSTAR power console. While the peak-to-peak ripple is similar, a higher characteristic frequency (~15 kHz) results from the switching frequency of the power supply’s DC-DC converter. Both the Brayton PMAD system and the laboratory power supply easily meet the NSTAR beam power specification of less than 5 percent voltage ripple.

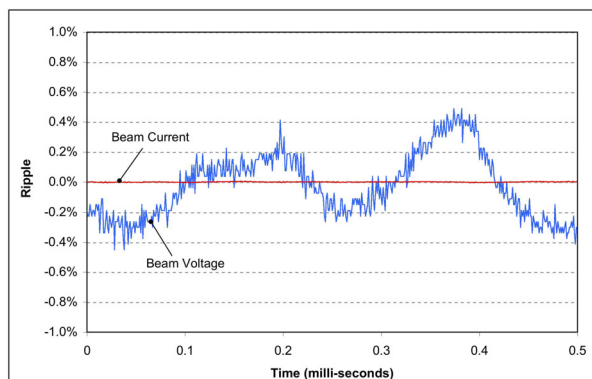


FIGURE 13. Current and Voltage Ripple with the Brayton Alternator

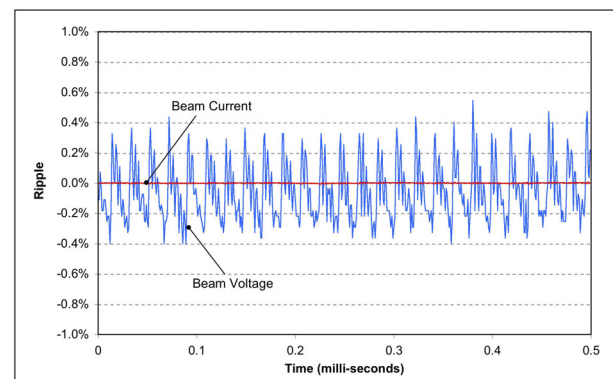


FIGURE 14. Current and Voltage Ripple with a Laboratory DC Power Supply

CONCLUSION

The successful completion of this test demonstrated the end-to-end electrical throughput from a Brayton power conversion unit to an ion thruster, and marked the first-ever coupling of a Brayton turbo-alternator to an ion thruster beam supply. It further demonstrated the use of high efficiency AC to DC conversion using a transformer/rectifier/filter design approach that is applicable to future JIMO-class AC Power Processing Units. Ion thruster recycle fault protection was demonstrated using high speed load switching without adverse energy deposition on the thruster grids or harmful transients on the Brayton rotor. The use of existing equipment for the Brayton unit and ion thruster provided a cost-effective approach to addressing the critical electrical interface between the power conversion unit and the electric propulsion system. While this test was limited in power to the 2 kW-class, the power conversion system and power management techniques are applicable to the higher power levels anticipated for NEP.

REFERENCES

- Mason, L.S., "A Power Conversion Concept for the Jupiter Icy Moons Orbiter," NASA/TM—2003-212596, September 2003.
- Hervol, D., Mason, L., and Birchenough, A., "Experimental Results from a 2 kW Brayton Power Conversion Unit," NASA/TM—2003-211999, January 2003.
- Mason, L.S., Shaltens R.K., and Espinosa, W.D., "Experimental Data for Two Different Alternator Configurations in a Solar Brayton Power System," NASA TM-107509, July 1997.
- Brophy, J.R., "NASA's Deep Space 1 Ion Engine (Plenary)," Review of Scientific Instruments, Volume 73, Number 2, February 2002.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE February 2004		3. REPORT TYPE AND DATES COVERED Technical Memorandum
4. TITLE AND SUBTITLE Experimental Investigations From the Operation of a 2 kW Brayton Power Conversion Unit and a Xenon Ion Thruster			5. FUNDING NUMBERS WBS-22-973-80-10	
6. AUTHOR(S) David Hervol, Lee Mason, Arthur Birchenough, and Luis Pinero				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration John H. Glenn Research Center at Lewis Field Cleveland, Ohio 44135-3191			8. PERFORMING ORGANIZATION REPORT NUMBER E-14419	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001			10. SPONSORING/MONITORING AGENCY REPORT NUMBER NASA TM-2004-212960	
11. SUPPLEMENTARY NOTES Prepared for the Space Technology and Applications International Forum (STAIF-2004) sponsored by the American Institute of Physics, Albuquerque, New Mexico, February 8-12, 2004. David Hervol, Analex Corporation, Brook Park, Ohio 44142; and Lee Mason, Arthur Birchenough, and Luis Pinero, NASA Glenn Research Center. Responsible person, Lee Mason, organization code 5490, 216-977-7106.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category: 20 Available electronically at http://gltrs.grc.nasa.gov This publication is available from the NASA Center for AeroSpace Information, 301-621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) A 2 kW Brayton Power Conversion Unit (PCU) and a xenon ion thruster were integrated with a Power Management and Distribution (PMAD) system as part of a Nuclear Electric Propulsion (NEP) Testbed at NASA's Glenn Research Center. Brayton converters and ion thrusters are potential candidates for use on future high power NEP missions such as the proposed Jupiter Icy Moons Orbiter (JIMO). The use of existing lower power test hardware provided a cost-effective means to investigate the critical electrical interface between the power conversion system and ion propulsion system. The testing successfully demonstrated compatible electrical operations between the converter and the thruster, including end-to-end electric power throughput, high efficiency AC to DC conversion, and thruster recycle fault protection. The details of this demonstration are reported herein.				
14. SUBJECT TERMS Nuclear electric power generation; Nuclear electric propulsion; Brayton cycle			15. NUMBER OF PAGES 15	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT	